LASER EYE INJURIES

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The Human Eye is the Most Important Sensor on the Modern Battlefield

Laser Overview

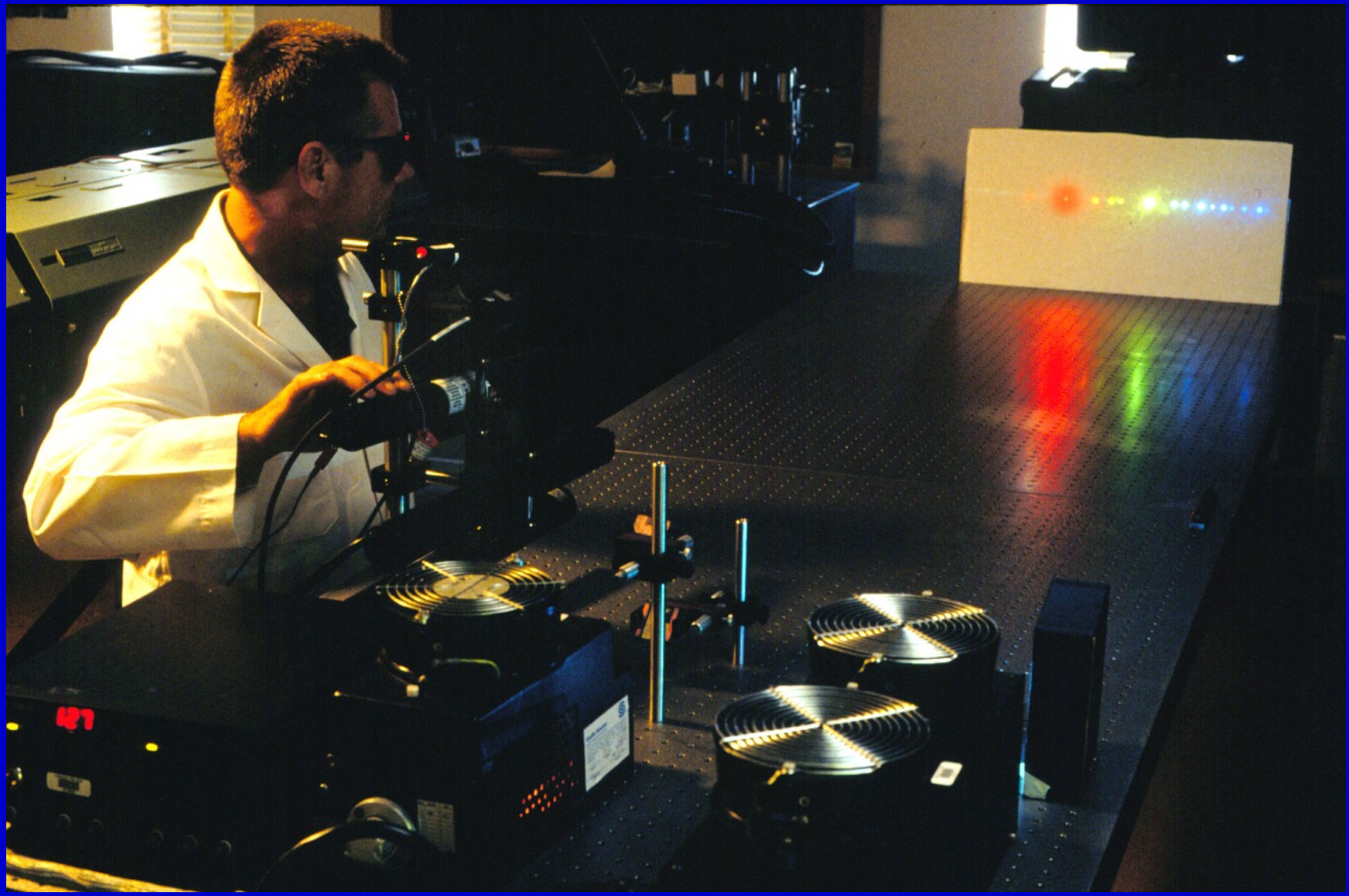
- Introduction
- Laser Classifications
- Laser Retinal Bioeffects
- US Army Laser Types
- Laser Injury Cases
- Evaluation of Laser Injuries

The Military Laser Injury Problem

- Military Lasers can produce eye injuries at tactical ranges
- Laser eye injury is predominantly an Army problem because of
  “close,” line of site engagement ranges and use of magnifying optics
- Injuries likely in macular or fovea area and probably bilateral
  (both eyes)

The Military Laser Injury Problem

- Multiple retinal injury sites anticipated
- Non-injuring levels of laser exposure will disrupt mission performance at greater ranges
- Current protection is adequate if threat is known or anticipated well in advance
- No accepted treatment



American National Standards Institute

- Classification of Lasers
  - small variation between US and European
- Potential to cause ocular damage

American National Standards Institute

- Class 1 - incapable of producing eye damage
  - maximum radiant emission of 0.4 uW
  - most inexpensive laser pointers
  - aiming device on M-16
- Class 2 - eye safe?
  - emit visible radiation (400-780 nm)
  - low power emissions (<1mW)

American National Standards Institute

- Class 3 - can cause injury upon direct viewing of the beam (5-500 mW or <10 J/cm 2 for a pulsed system)
  - 3A and 3B (3A- 5mW, 3B 6-500mW)
  - 3A deemed eye safe by reason that blinking will avert serious eye damage
  - 3B potential to cause serious eye damage

American National Standards Institute

- Class 4 - high power emissions (>500 mW or >10 J/cm 2)
  - all ophthalmic surgical lasers
  - laser range finders and target designators

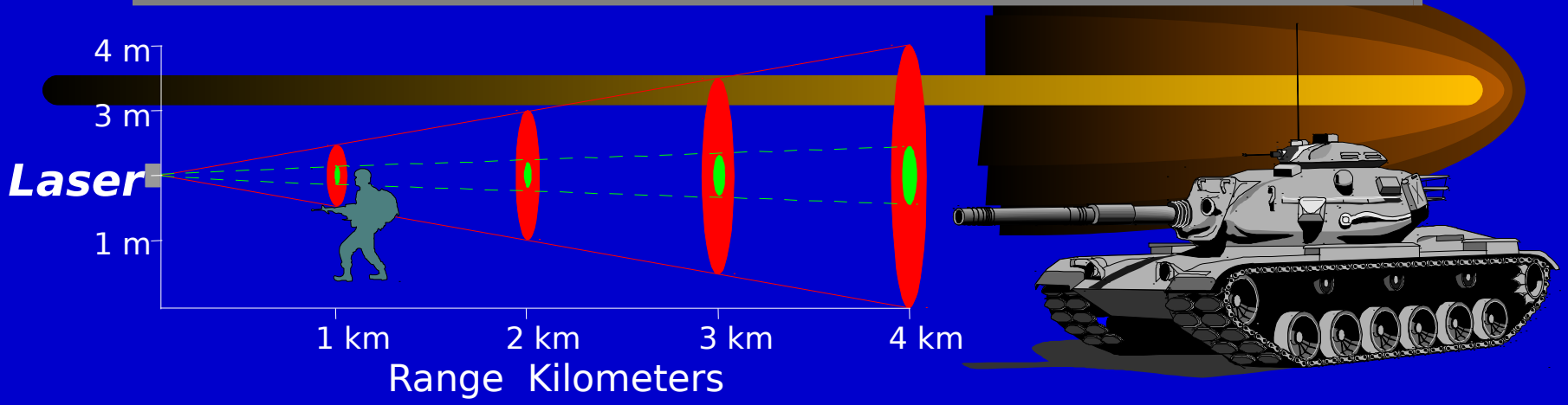
Laser Emission Characteristics

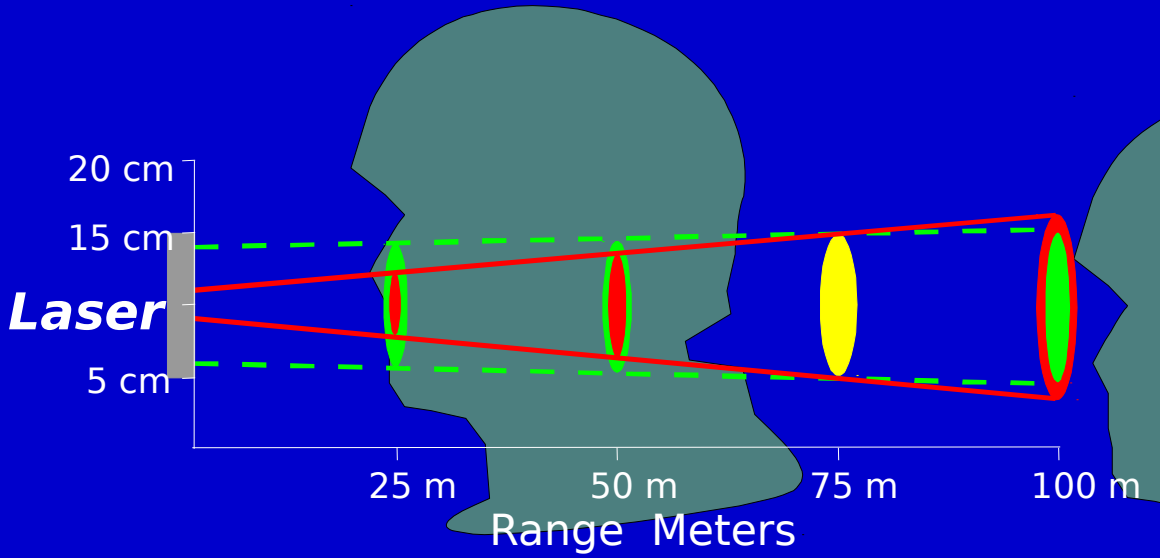
- Emission Durations
  - Single pulses as short as 10 femtoseconds (10^{-14} seconds)
    - like a flashbulb
  - Continuous wave (CW)
    - like an automobile headlight

Laser Emission Characteristics

- Repetitive pulses - Pulse repetition frequencies (single pulse to 10^{8} pps)
  - like a disco strobe
- Beam Divergence
  - small beam divergence (0.1 - 1.0 milliradians)
  - (e.g. 0.5 mr divergence - 50 cm beam diameter at 1 km)

Beam Diameter as a Function of Range





	Beam Divergence	Exit Beam Diameter
RED	1.0 mr	2 cm
GREEN	0.2 mr	8 cm

Laser Emission Characteristics

- Emission Wavelengths
  - Near ultraviolet to the far infrared
  - Usually highly monochromatic (single wavelength of color)

Laser Emission Characteristics

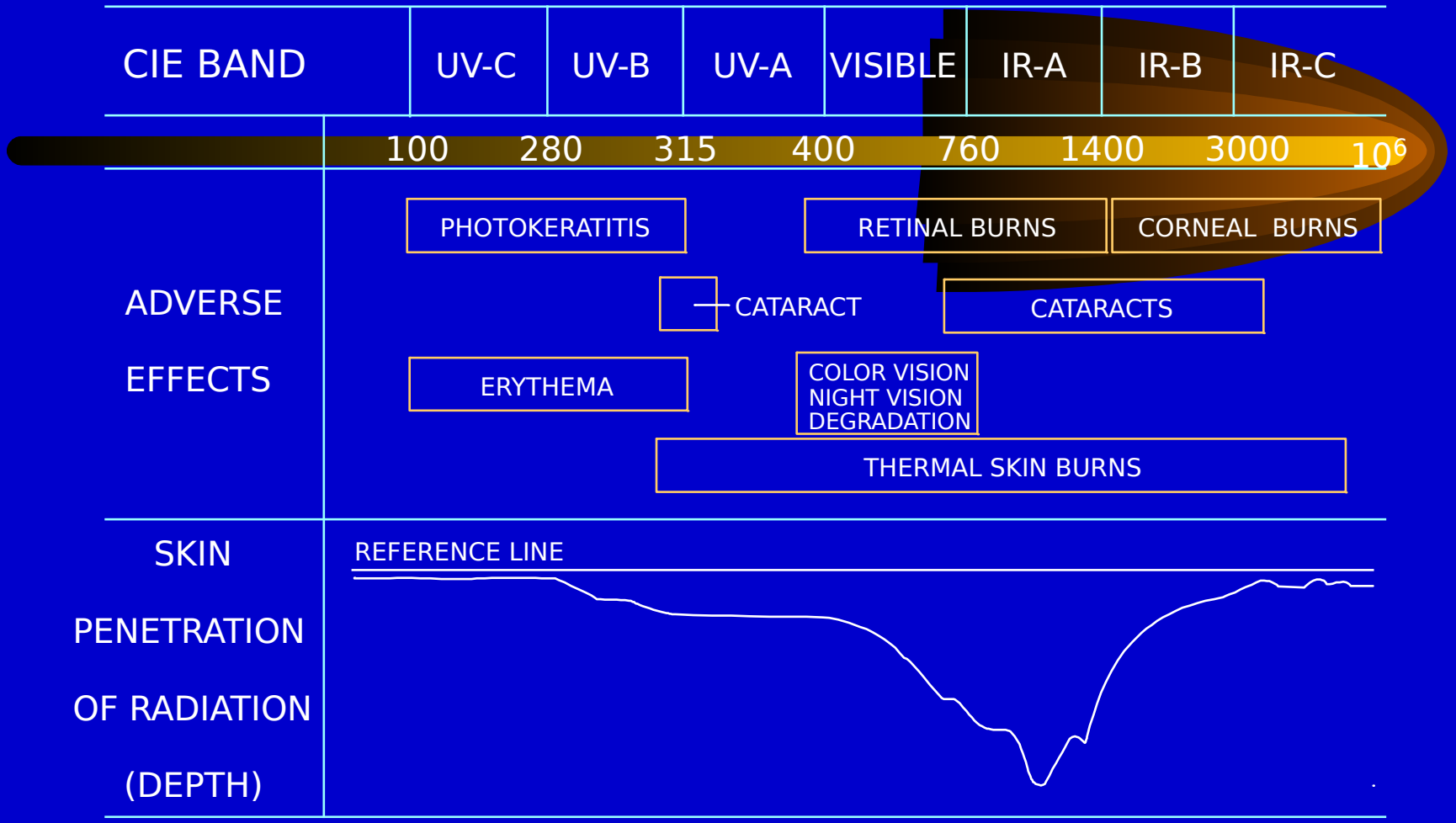
- 200-400 nm
  - UV light (A,B,C)
  - capable of producing eye damage
  - retina spared
  - electromagnetic radiation absorbed by the cornea and lens

Laser Emission Characteristics

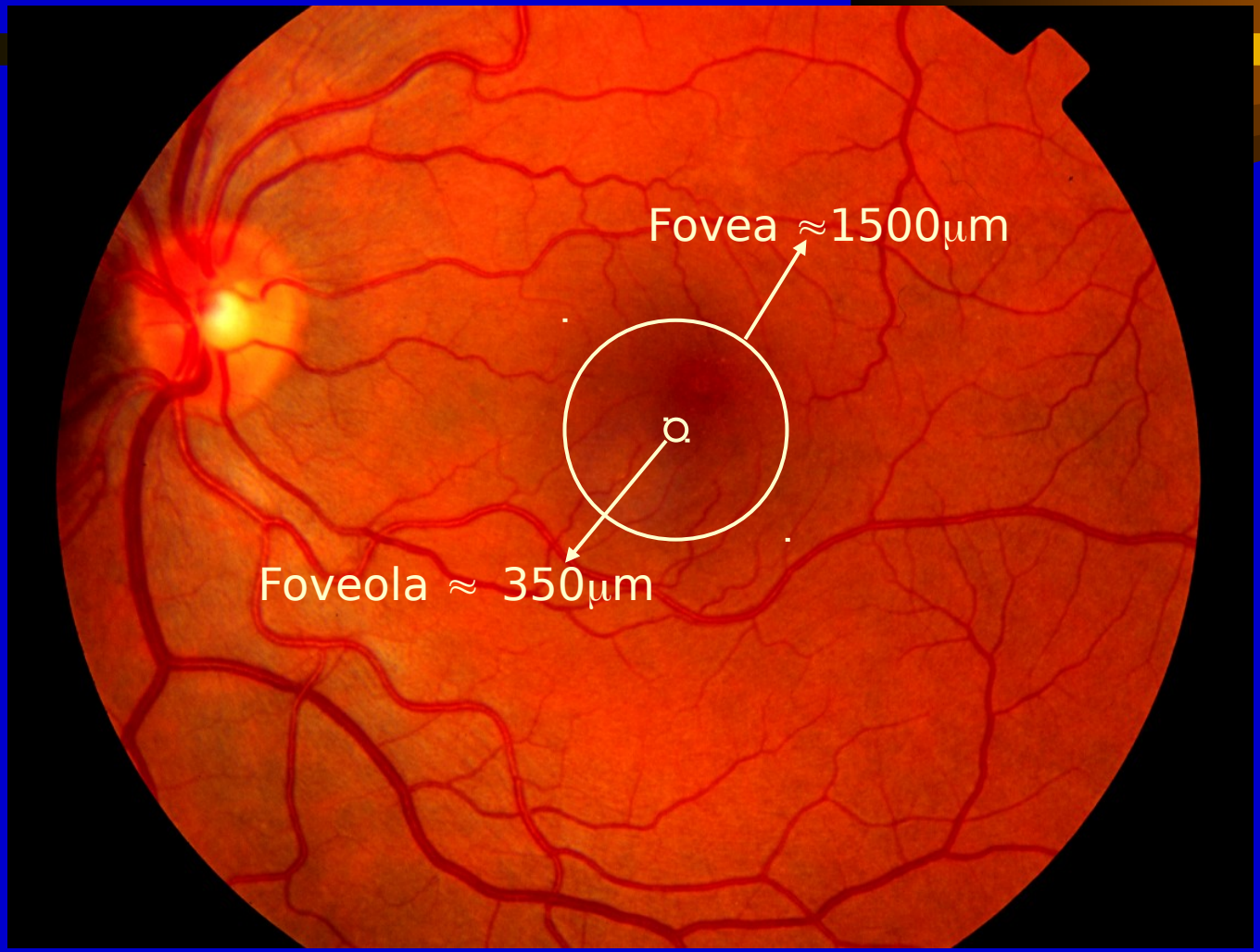
- 400-780 nm
  - visible light spectrum
  - absorbed by the RPE and Choroid

Laser Emission Characteristics

- 780-1400 nm
  - NIR-A laser
  - damage to retina and choroid
- >1400 nm
  - FIR laser
  - corneal burns and cataracts
  - retina spared


CIE BAND
UV-C
UV-B
UV-A
VISIBLE
IR-A
IR-B
IR-C
100
280
315
400
760
1400
3000
10^6
ADVERSE EFFECTS
PHOTOKERATITIS
RETINAL BURNS
CORNEAL BURNS
CATARACT
CATARACTS
ERYTHEMA
COLOR VISION
NIGHT VISION
DEGRADATION
THERMAL SKIN BURNS
SKIN PENETRATION OF RADIATION (DEPTH)
REFERENCE LINE

Retinal Anatomy



Laser Induced Retinal Bioeffects

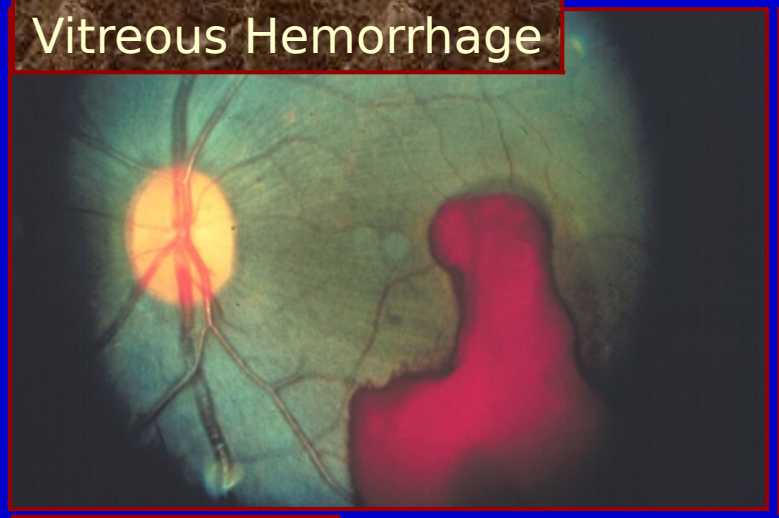
- Temporary Effects
  - Glare/Dazzle effects
  - Flash effects (“after image”)
- Prolonged - Permanent Effects
  - Retinal “burn” (edema)
  - Sub-retinal hemorrhage
  - Vitreous hemorrhage

Laser Induced Retinal Bioeffects

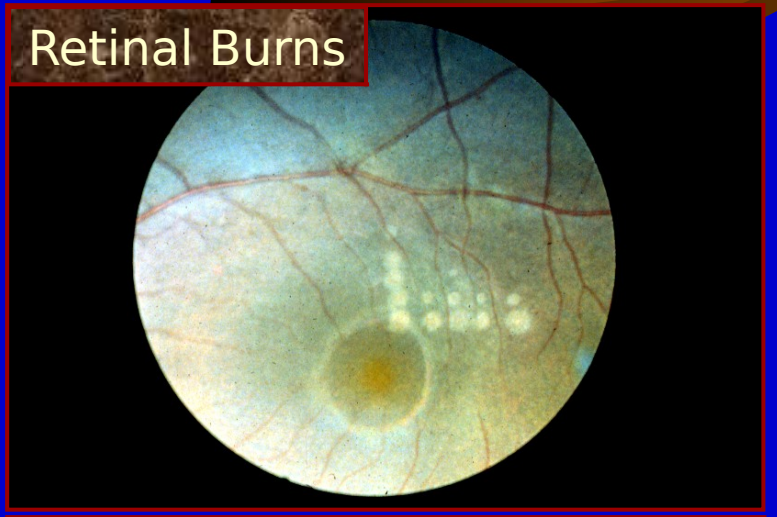
- Secondary Effects
  - Retinal hole formation
  - Scar formation
  - Nerve fiber layer alterations
  - Epiretinal membrane
  - Choroidal neovascular membrane

Laser Bioeffects

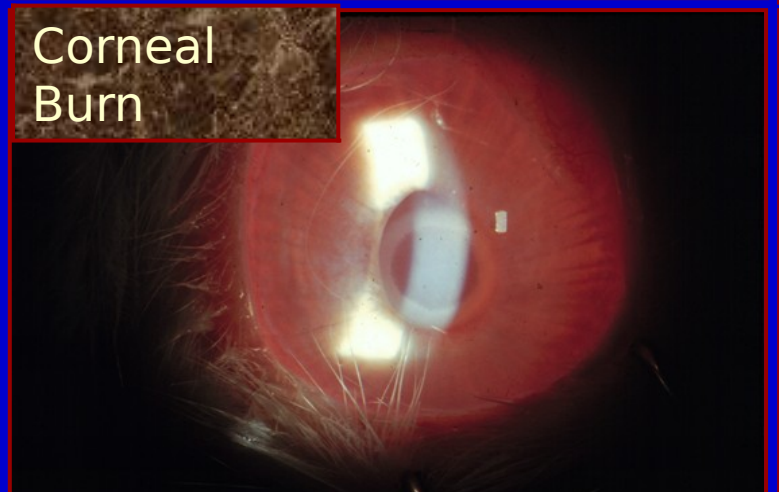
Vitreous Hemorrhage



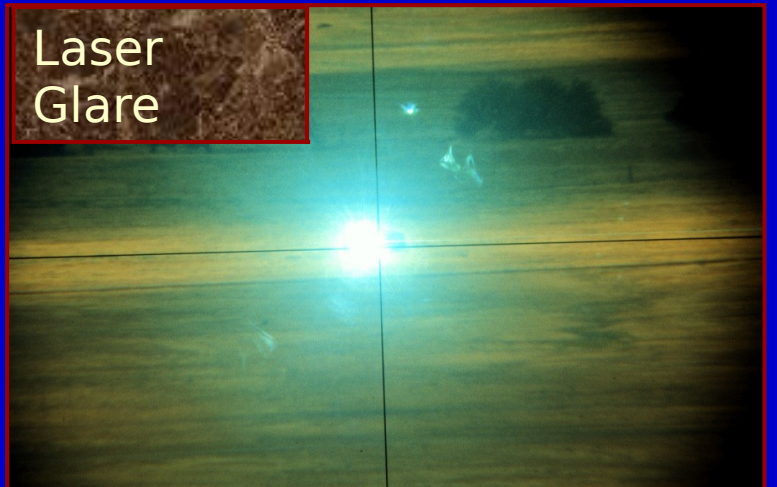
Retinal Burns

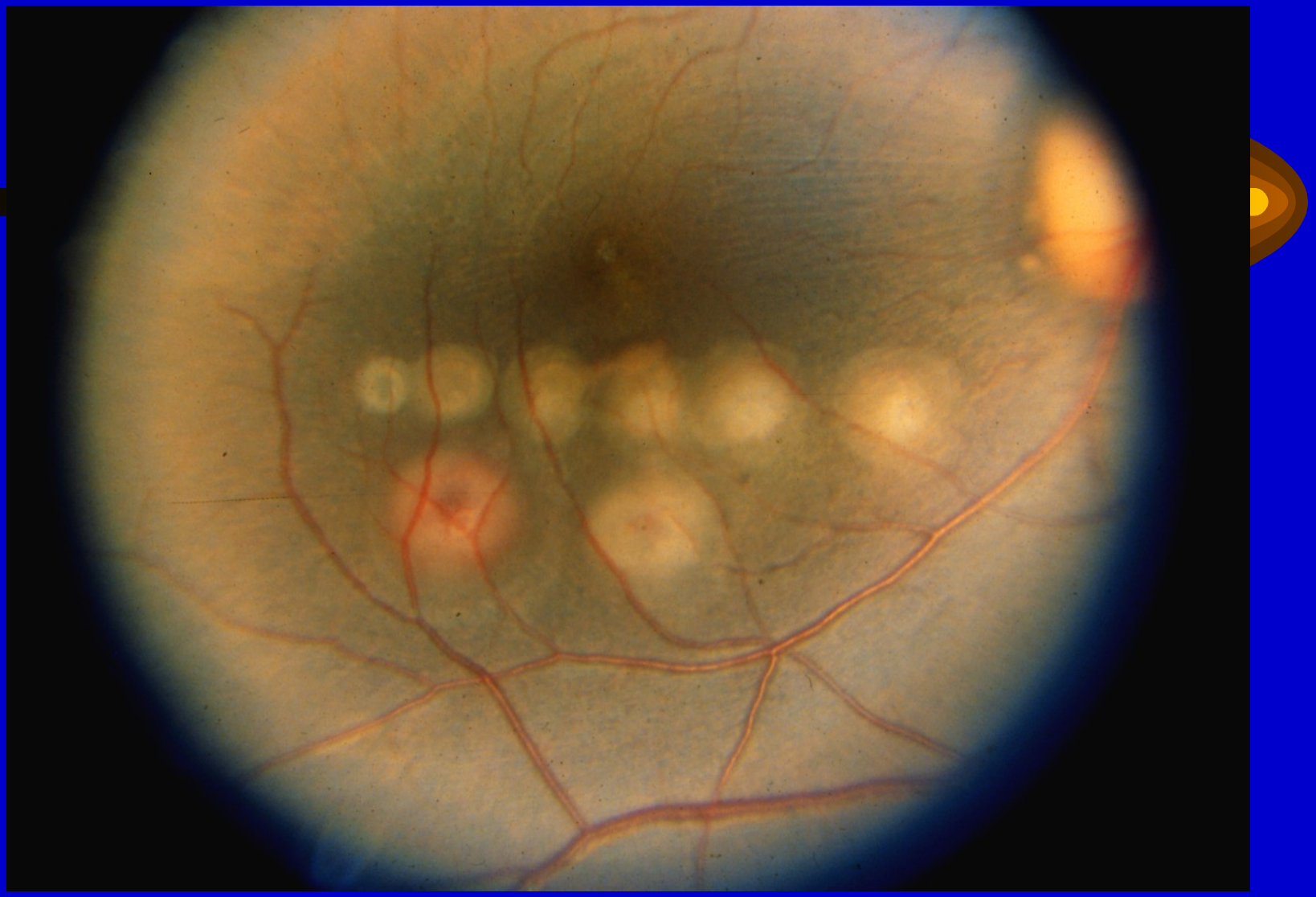


Corneal Burn

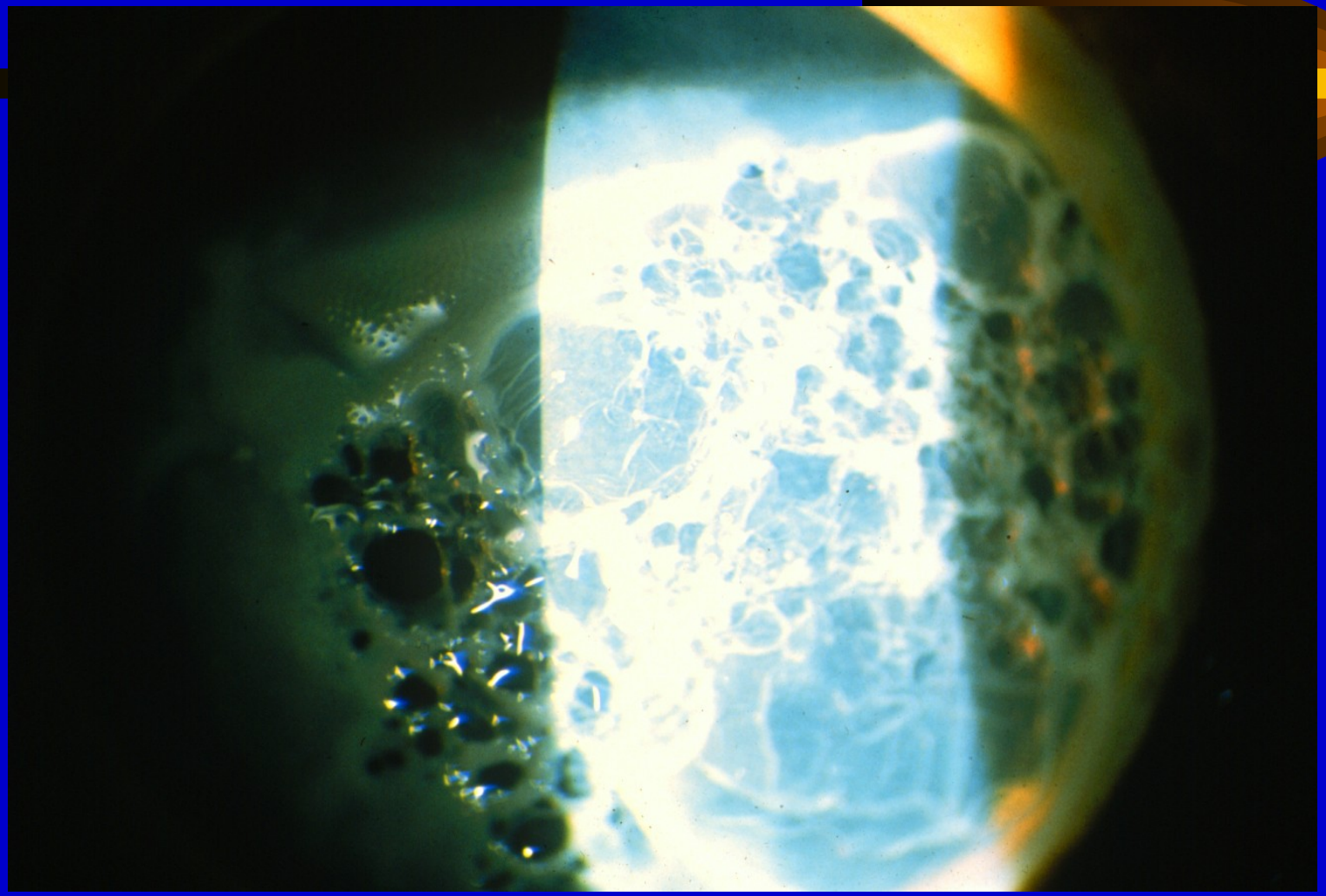


Laser Glare



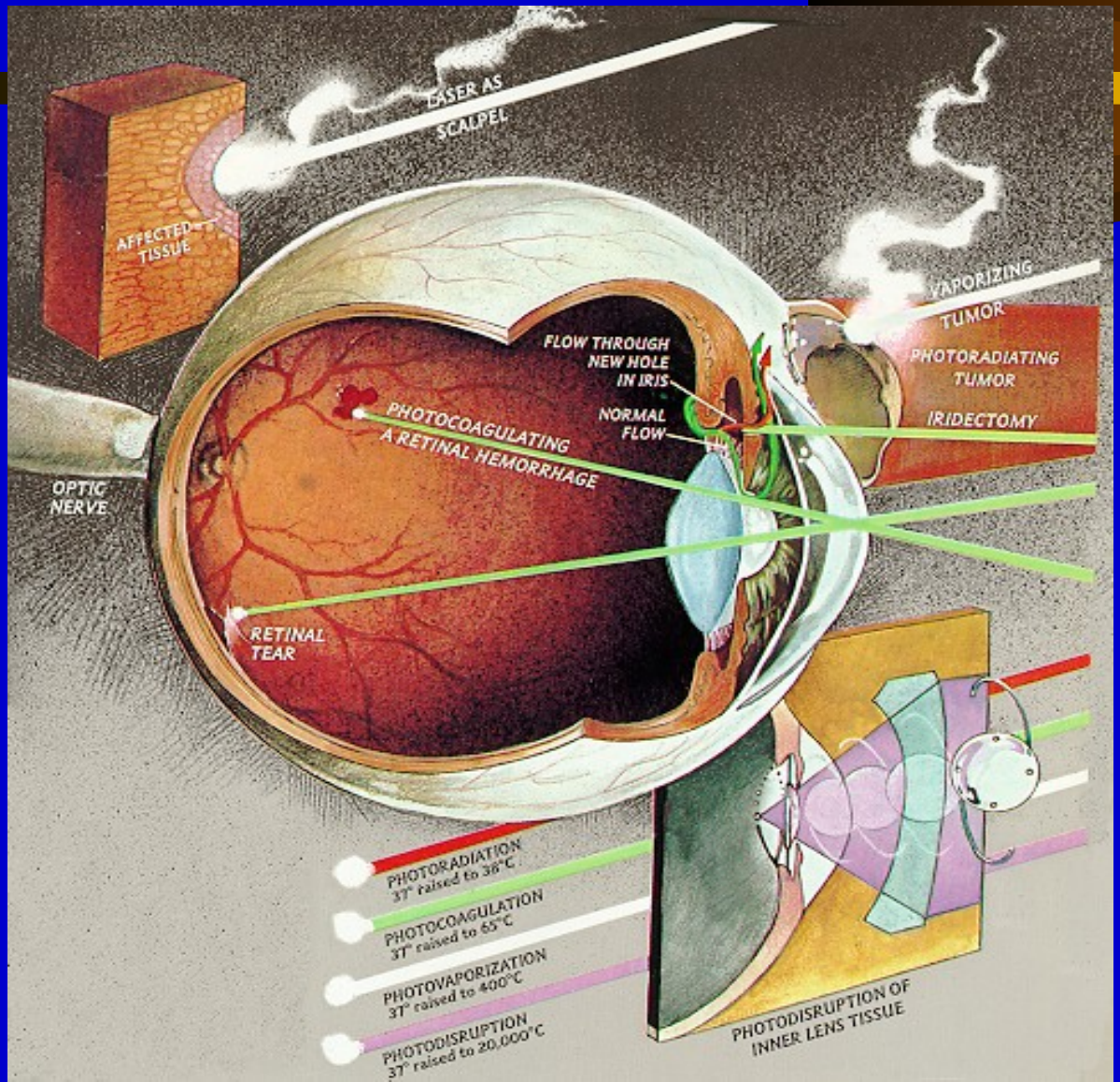


Severe CO_2 Laser Induced Corneal Burn

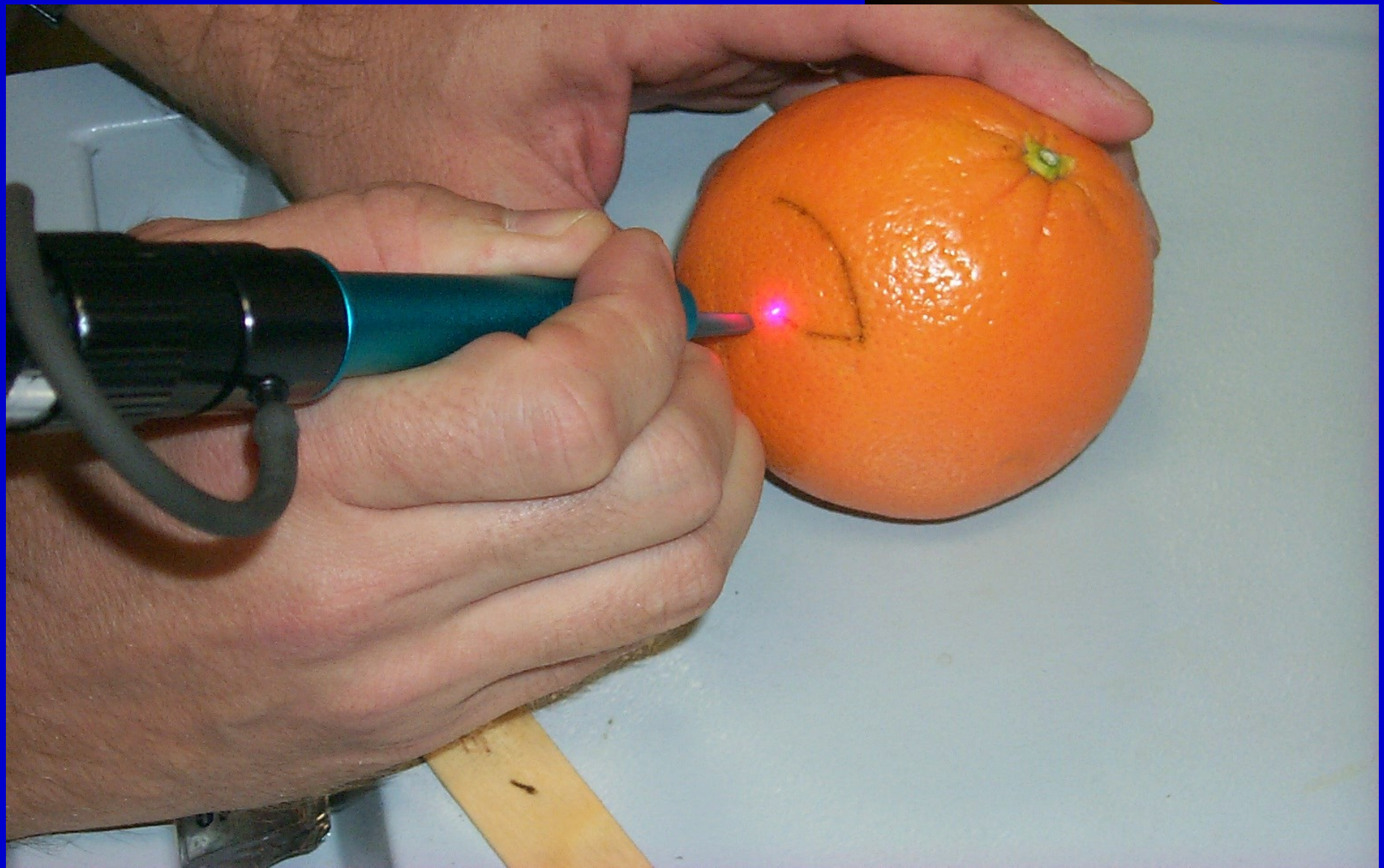


75 w/cm^2, 100 msec

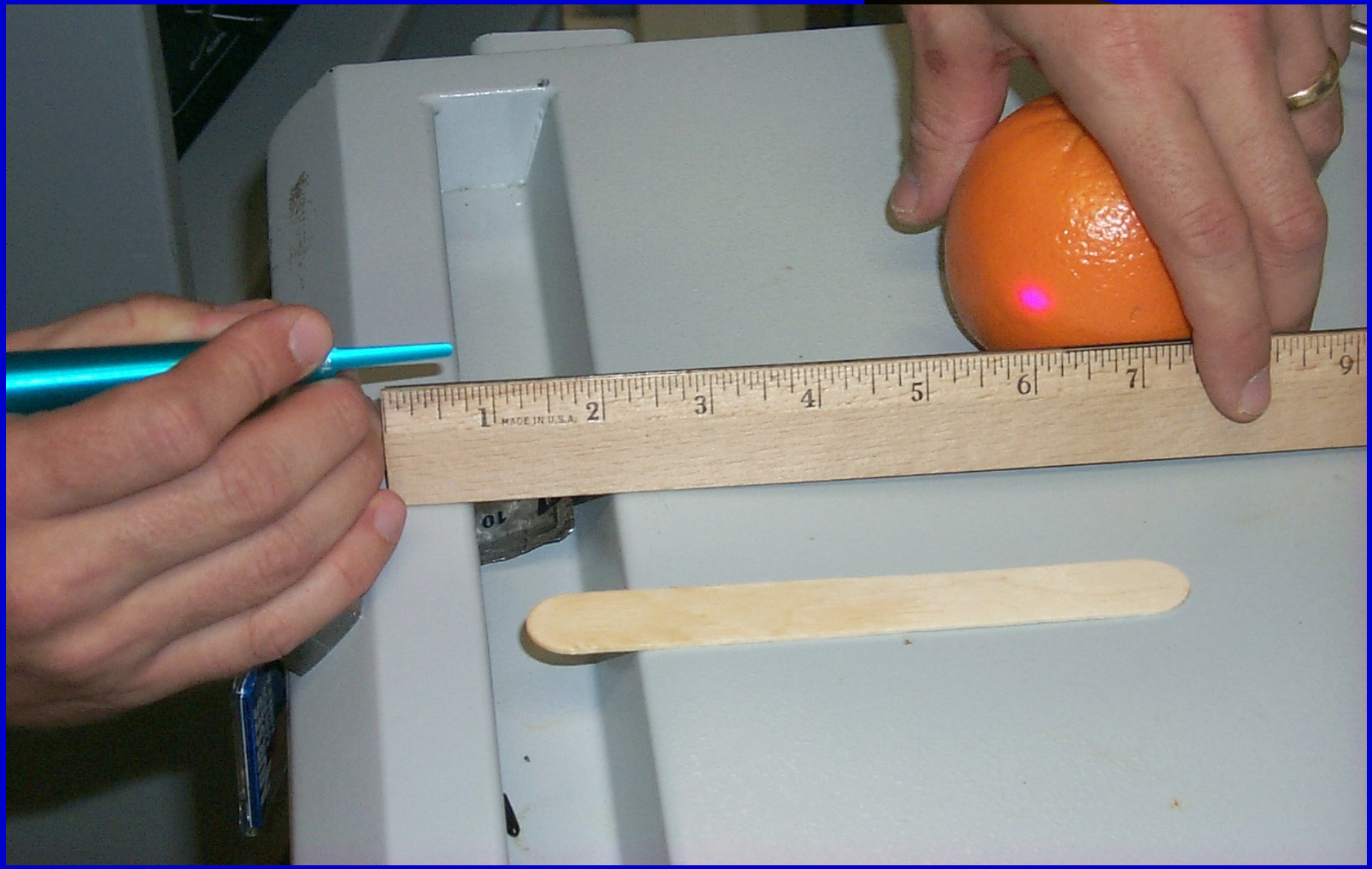
Ophthalmic Surgical Laser Uses



CO_2 Laser "Scalpel"
8 Watts, CW



CO2 Laser Defocused



US ARMY LASER TYPES

- Laser range finders
  - Ruby 694 nm
  - Nd:YAG 1064 nm
  - CO_2 10,600 nm
- Target Designator
  - Nd:YAG 1064 nm

US ARMY LASER TYPES

- MILES gear
  - Gallium-arsenide 905 nm
- M55 tank gunnery trainer
  - Helium-neon 642 nm

Laser Training Devices

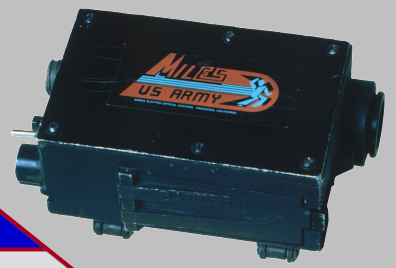
Multiple

I ntegrated

L aser

E ngagement

S imulator



Laser Designator Systems

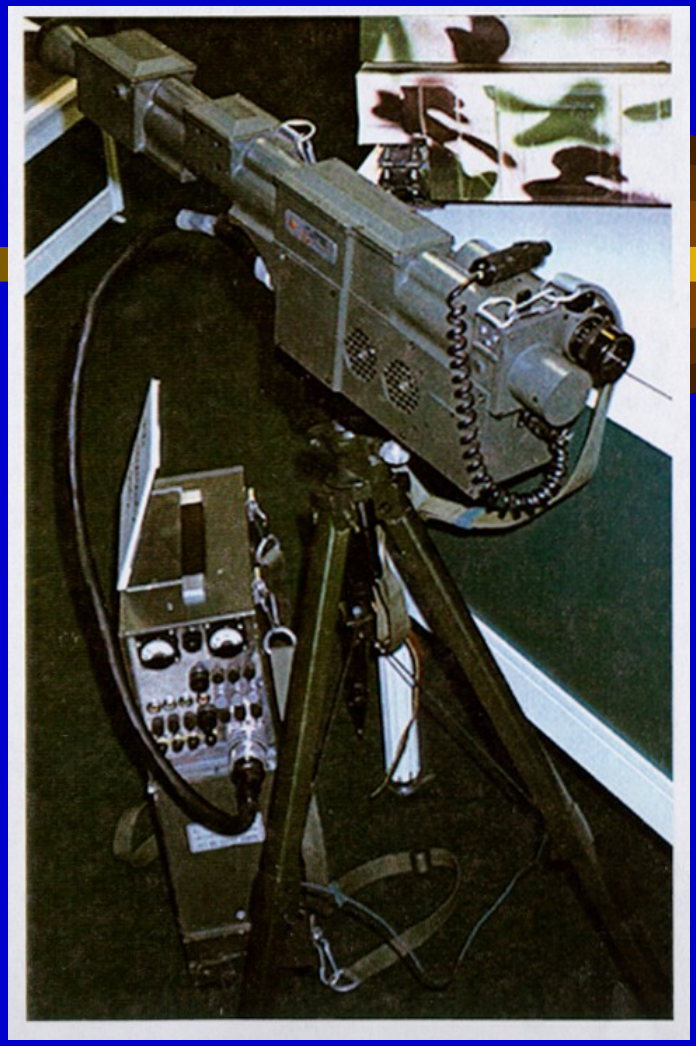
GLLD

MULE

ANVLQ-7
Stingray Combat
Protection
System

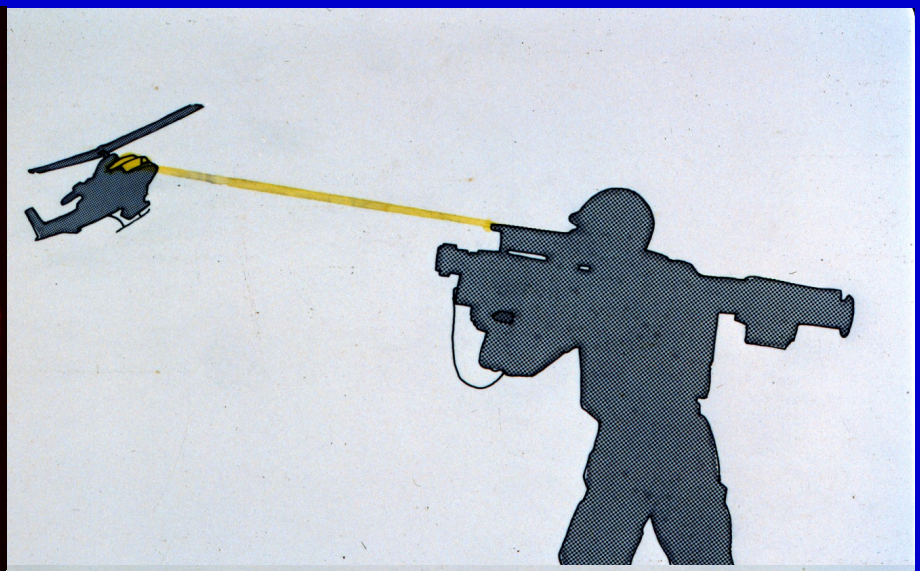
Prototype Hand Held
Laser
Countermeasure
System

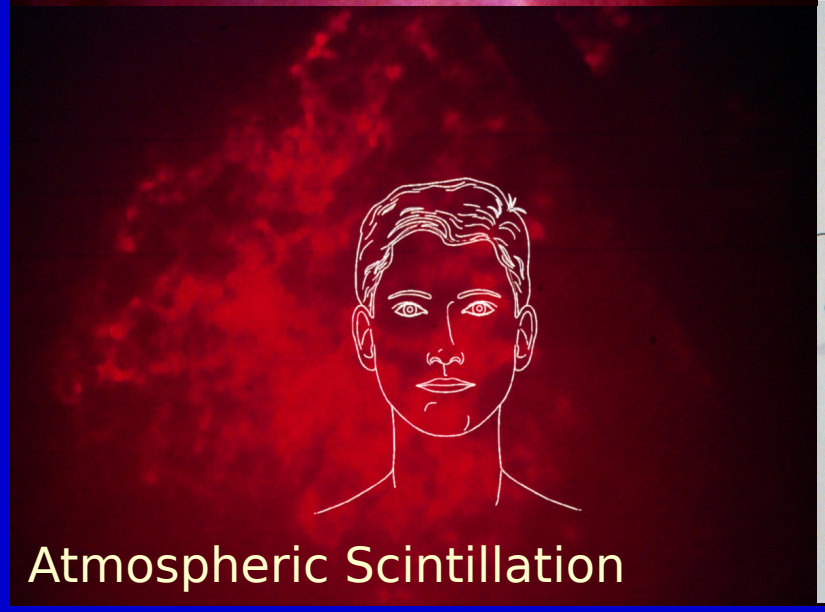
Iranian Target Rangefinder



Chinese ZM87

Perceived Glare




Atmospheric Scintillation

Visible and Near Infrared Laser Eff

- Q - Switched Laser: 100mj / pulse; .25mrad divergence
- Optics: M - 17 Binoculars
- W / O Optics: 7mm pupil diameter
- Propagation Model: Clear, non-turbulent atmosphere

Wavelength	Vitreous Hemorrhage		Retinal Burn	
nm	w/o optics	optics	w/o optics	optics
532	0.6 km	2.9 km	3.2 km	10.5 km
694.3	0.47 km	2.4 km	1.7 km	6.6 km
1064	--------	0.25 km	0.61 km	3.0 km

Ocular Effects as a Function of Range

Frequency Doubled Neodymium Laser at 532 nm

	0.1 J - 0.25 mr		0.5 J - 0.15 mr	
	Clear	Fog	Clear	Fog
50 mm Optics				
Vitreous Hemorrhage	2.9 km	0.39 km	7.9 km	0.54 km
Retinal Burn	12.5 km	0.7 km	23.0 km	0.88 km
7 mm Pupil				
Vitreous Hemorrhage	0.6 km	0.19 km	2.0 km	0.29 km
Retinal Burn	4.0 km	0.45 km	10.0 km	0.60 km
3 mm Pupil				
Vitreous Hemorrhage	0.21 km	0.10 km	0.75 km	0.16 km
Retinal Burn	1.9 km	0.33 km	5.7 km	0.47 km

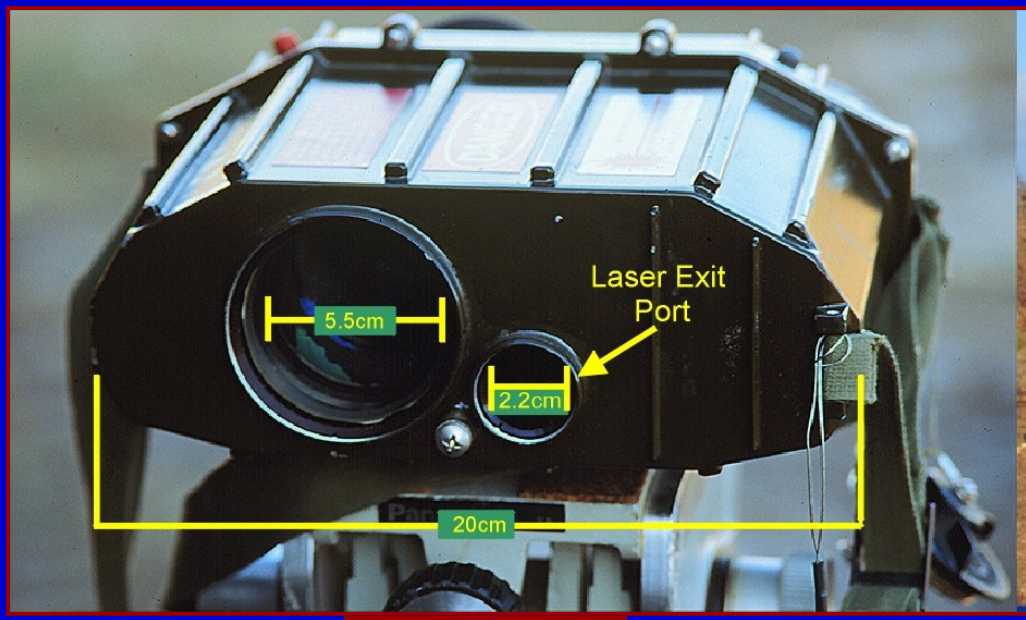
Report of Laser Injury by Dr. C. David Decker

"When the beam struck my eye I heard a distinct popping sound, caused by a laser-induced explosion at the back of my eyeball. My vision was obscured almost immediately by streams of blood floating in the vitreous humor, and by what appeared to be particulate matter suspended in the vitreous humor. It was like viewing the world through a round fishbowl full of glycerol into which a quart of blood and handful of black pepper have been partially mixed. There was local pain within a few minutes of the accident, but it did not become excruciating. The most immediate response after such an accident is horror. As a Vietnam War Veteran, I have seen several terrible scenes of human carnage, but none affected me more than viewing the world through my blood-filled eyeball. In the aftermath of the accident I went into shock, as is typical in personal injury accidents". (Nd:YAG Laser at 1064 nm, 10 nsec pulse, Total Intraocular Energy ≈ 6 mJ)

Laser Eye Injury Case (19 yr old Pvt.)

- Injured while viewing the exit aperture of a hand-held range finder at arms length.
- Ophthalmology eval revealed vitreous hemorrhage, 2 intense retinal burns, 1 lesser and 1-2 minor retinal burns OD.
- VA 20/200 OD and 20/20 OS, 24 hours post injury.

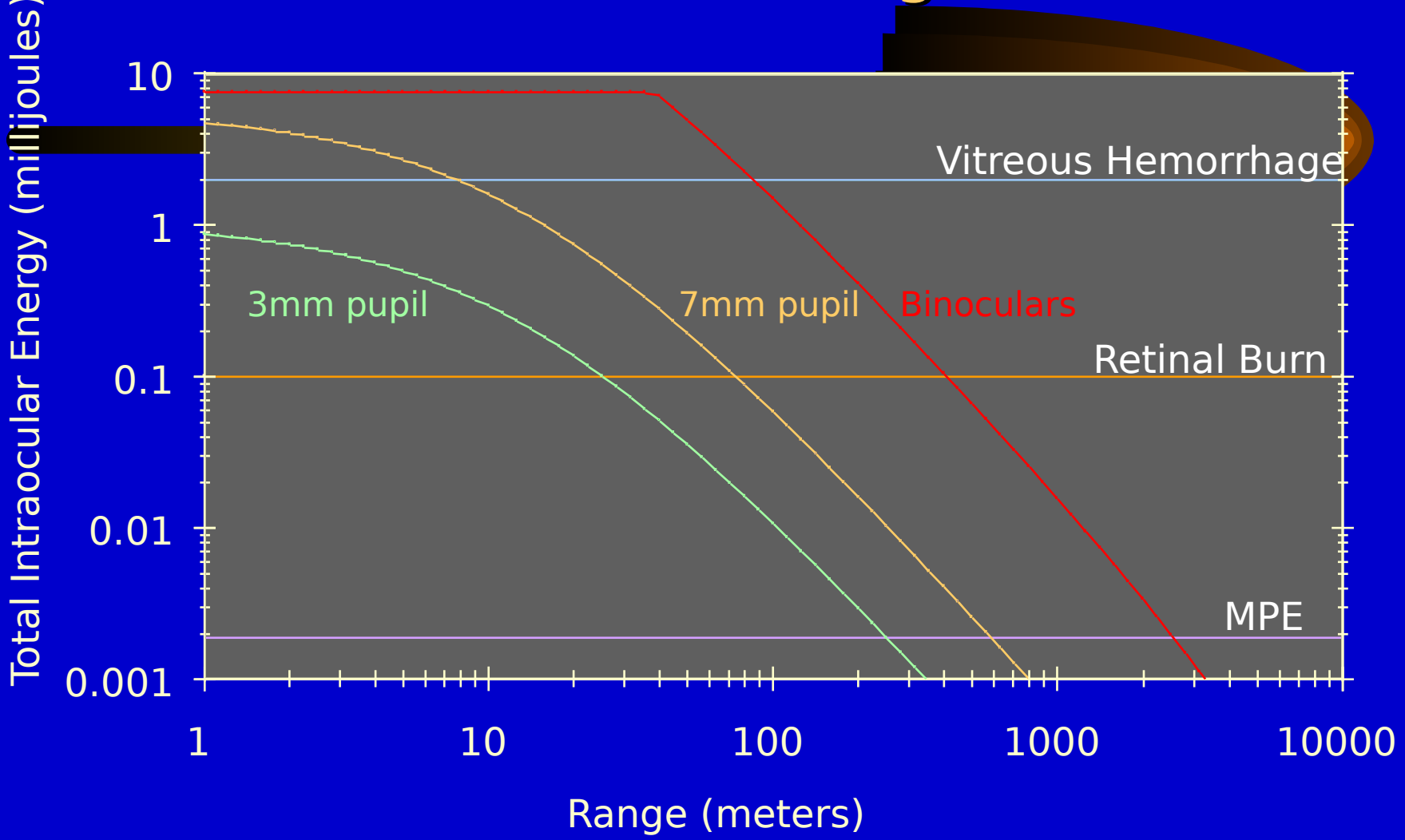
Laser Range Finder



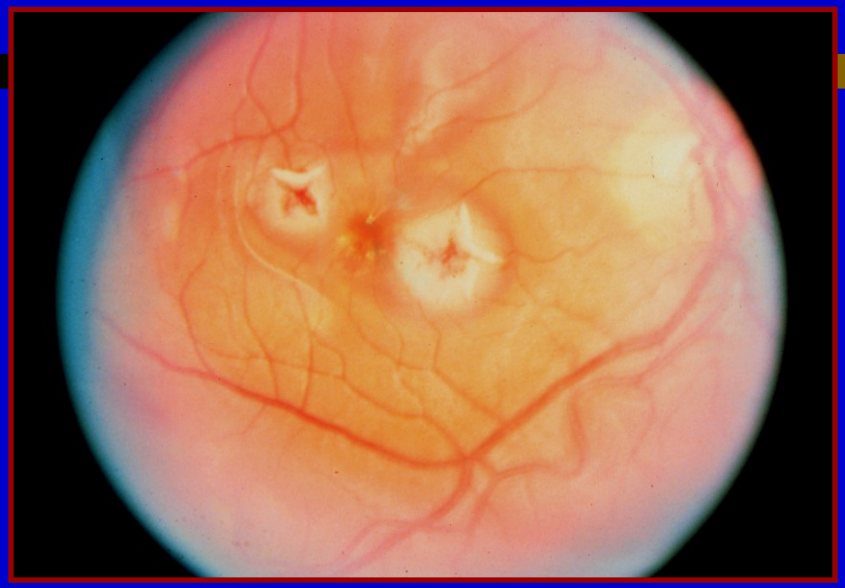
ANGVS-5

Laser Exposure
Scenarios

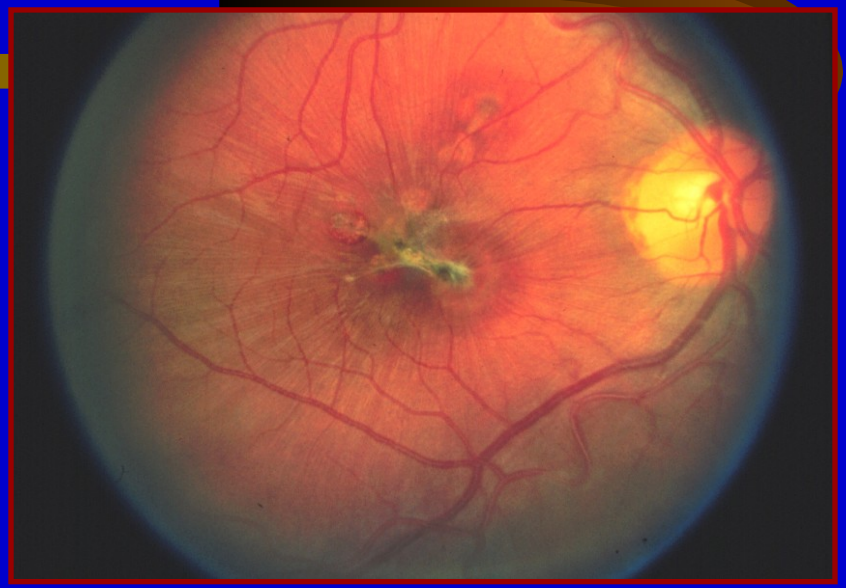
ANGVS5 Laser Rangefinder



ANGVS-5 Laser Rangefinder Accident



FOUR DAYS



TWO MONTHS

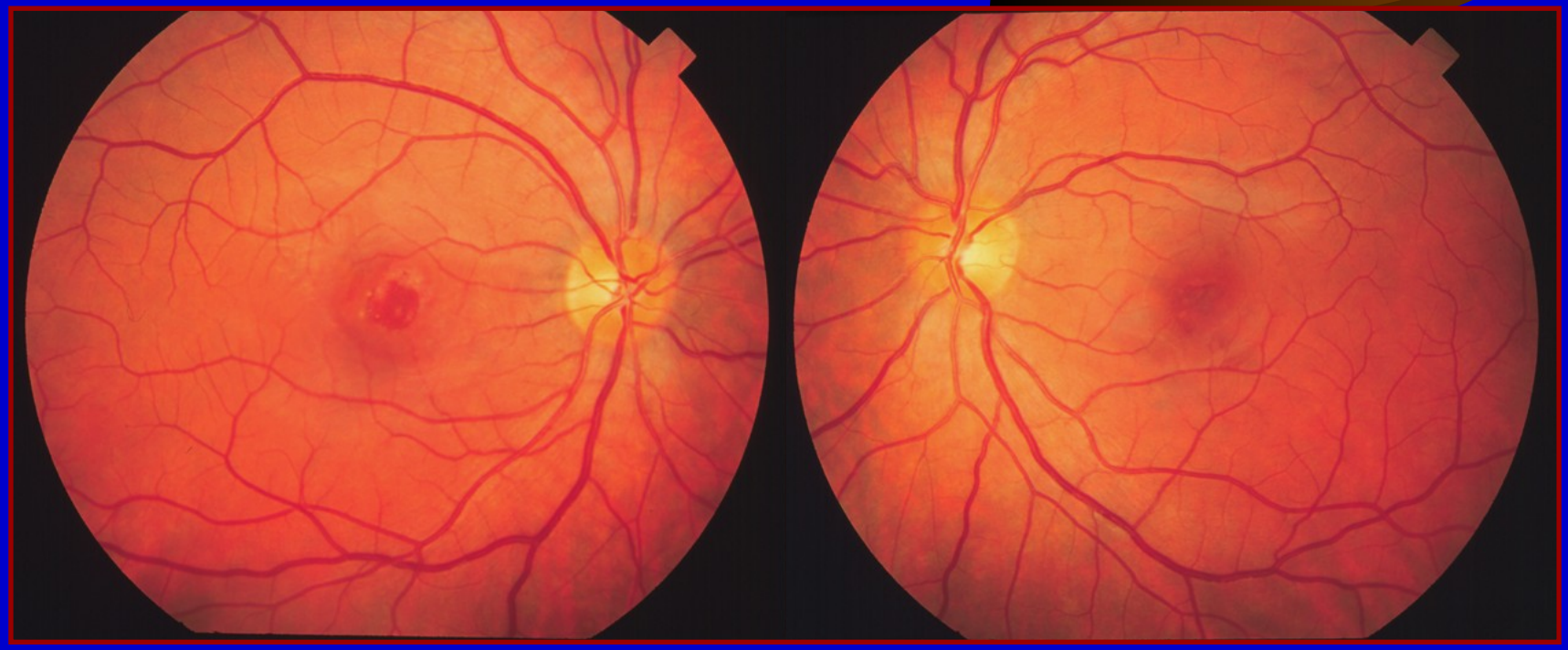
Visual acuity at 3 years < 20/200 (OD)
Medical discharge with 30% disability compensation

Laser Eye Injury
Case FLC (21 year old male Marine)

- ANGVS-5 Hand Held Laser Rangefinder Nd:YAG @1064 nm, 8 ns pulse, 15 mJ/pulse, 1 pulse every four seconds
- Exposed while attempting to connect external battery to laser (device wedged between his leg and vehicle)
- Bilateral exposures (one exposure in each eye due to small bea size) under bright midday luminance conditions
- Bilateral vitreous hemorrhage: VA (24 hrs) OD-20/50; OS-20/200 VA (18 mo) OD-20/400; OS-20/17
- OD injury complicated by epiretinal membrane and retinal hole formation requiring surgical intervention
- Medical Board and disability compensation

Military Laser Eye Injury

Case FLC (18 months post exposure)

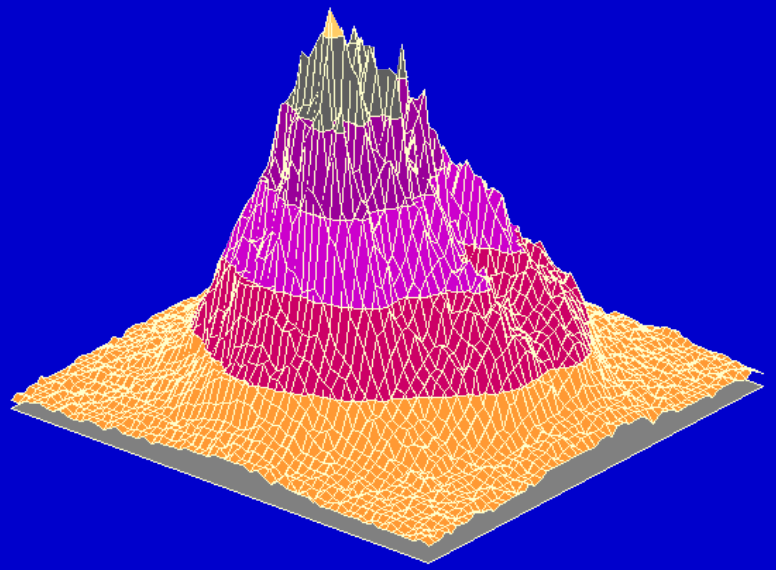


Macular hole OD

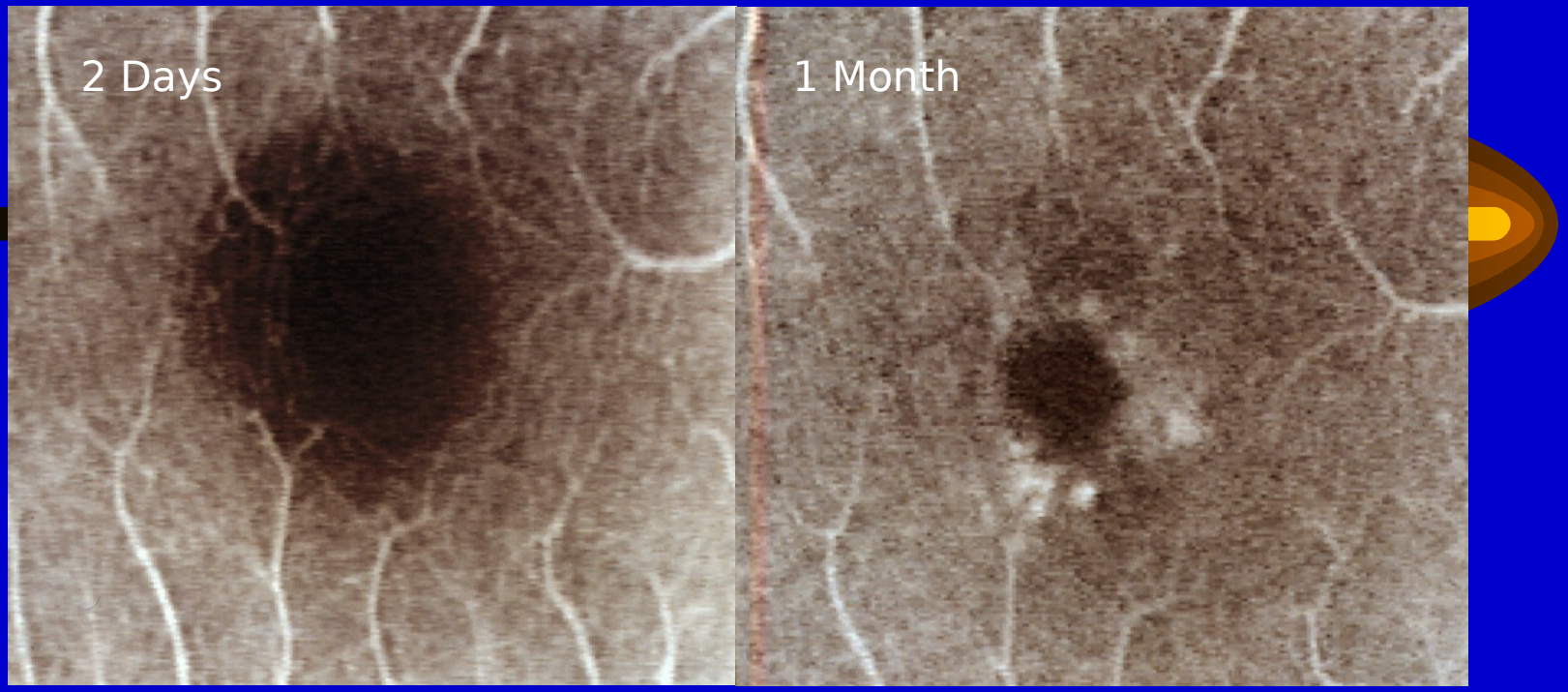
Fort Hood Accident Case (AP) (21 year old female technician)

- Viewed into 10 cm exit aperture of GLLD
  - Mistaken for eyepiece
  - Indoor test facility
- Initial VA 20/50-20/200 OD, 20/60 OS
- Bilateral retinal injury to macula
- R_X within 6 hours with high dose Solu-Medrol

GLLD Exposure Scenario



Four Days
One Month



Scanning Laser Ophthalmoscope (SLO) Fluorescein Angiogram: SLO late-stage fluorescein angiogram of AP(OD) at 2 days and 1 month after exposure. At 2 days, a large area of hypo-fluorescence or blockage over the foveal/macular area due to the mild confined hemorrhage. At 1 month, the size of the hypo-fluorescent area is reduced almost to the foveal avascular zone with small, focal hyper-fluorescent spots surrounding the fovea possibly indicative of an active recovery process.

Fort Hood Accident Case (AP) 2 Year Post Event

- CS depressed compared to control group
- Amsler Grid - still locate lesion
- VA recovery to 20/13 (OU) at 1 year
- No scar formation (R_X effective?)
  - Minimal impact on quality of life

Laser Incident in Bosnia October 1998

- Crew members reported seeing a red spot inside a UH-60.
- Complained of ocular discomfort after landing (tearing and photophobic).
- Exam revealed bilateral SPK and mild conjunctival injection.
- The following morning the pilot’s vision was 20/15 OU and the co-pilot’s vision was 20/20 OD and 20/25 OS

Laser Incidents in Bosnia October 1998

- Crew evaluated at BAMC and BAFB.
- **Final Assessment**: The anterior segment observations in the crew members was not related to the observation of the red laser spot. The small red laser spot observed by the crew members was most likely from a sighting laser or an accurately directed laser pointer.
- **Recommendation**: Additional training and information on lasers and their ocular effects.

Military Laser Accident Cases

- Tissue response
  - Retinal and vitreous hemorrhage
  - Multiple macular lesions resulted in bridging fibrosis
  - Retinal hole and scar formation, nerve fiber layer damage

Military Laser Accident Cases

- Visual Performance
  - Lesion location(s) important
  - Low and high spatial frequency contrast sensitivity changes
  - Pursuit tracking performance altered when acuity was near normal
- Treatment needed
  - High dose steroids effective?
  - Retinal surgery

Laser-Induced Retinal Injury Recovery

- Changes occur over a period of time (months to years)
- Visual system goes through a series of adaptations to re-establish and optimized function

Laser-Induced Retinal Injury Diagnosis

- Rapid screening (VA and Amsler Grid)
- Experienced ophthalmologist required for differential diagnosis
- Ophthalmoscopy and visual function (VA, FA, CS, Amsler Grid, Color vision, Humphrey Fields)

Laser-Induced Retinal Injury Diagnosis

- Standardization difficult due to wide variability in the presentation of laser-induced ocular injury
- Time critical for R_x (if any!)
- Follow-up examination(s) required
- Situational assessment important to diagnosis

Laser-Induced Retinal Injury Diagnosis

- New tools are being developed
  - Field Portable, Telemedicine-Ready Ophthalmoscopes

Laser Injury Evaluation Center

- Medical Aspects
- Laser / Laser Safety Analysis
- Laser Bioeffects Comparisons
- Dose Estimates
- Foreign Science Analysis
- Laser Injury Register

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An ounce of protection is worth a pound of cure.

Las Vegas Hotel Laser “Blinds” Southwest Pilot

- **Incident:** Southwest Airlines Flight departs McCarran International Airport near Las Vegas at 2012 hrs on October 30, 1995. About 3 miles into the flight while in an ascending right turn at an altitude of 2,000-3,000 feet, the pilot was exposed to a bright blue-green flash and experienced sudden, painless decrease in vision OD, requiring the other pilot to “grab the controls.”

Las Vegas Hotel Laser "Blinds" Southwest Pilot

- **Pilot:** "When the laser hit my eye, time stopped for me. Of course, the airplane was still flying at 250 miles per hour. Had it hit me and the other pilot simultaneously, I shutter to think what would have happened."
- **Medical:** Pilot was evaluated at Brooks AFB on 7 November. There were no findings that could be associated with the exposure incident. Corrected visual acuities were 20/20 or better.